Title: ETWG Report and System upgrades for Spring 2015 mmVLBI Campaign

Date: Nov 13, 2014 09:00 AM

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Abstract: Convened in the summer of 2013, the EHT Technical Working Group (ETWG) was tasked with:
1. Survey the capabilities at all EHT facilities
2. Establish a set of specifications for future EHT observations
3. Outline the technical developments needed to reach these goals
4. Based on prioritized science objectives, formulate a project roadmap that is grounded in technical feasibility with the resources available.
This overview will report on the findings and conclusions arrived at by the ETWG and present specifications for future EHT observations at 230 and 345 GHz. I will also briefly discuss subsequent technical developments and the rollout of new equipment for the 2015 EHT observing campaign that will for the first time deploy recording at 16 Gb/s. With a relatively modest expansion over the next couple of years this mmVLBI system will be capable of 64 Gb/s for an aggregate bandwidth of 16 GHz i.e. 8x the bandwidth of existing EHT observations.

Radboud Universiteit Nijmegen

EventHorizonTelescope

Report from ETWG and System Upgrades for the Spring 2015 mmVLBI Campaign

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Allegro, ALMA ARC node, Leiden Observatory, Netherlands

EHT Technical Working Group

Remo Tilanus (chair), *IMAPP, Radboud University*[*]

Geoff Crew, *MIT Haystack*

Yusuke Kono, *NOAJ*

Dan Marrone, *Univ. of Arizona*

Satoki Matsushita, *ASIAA*

Vincent Piétu, *IRAM*

Dick Plambeck, *CARMA*

Alan Roy, *MPIfR*

Jonathan Weintroub, *SAO*

and

Shep Doeleman[10] (PI EHT, expert & advisory role)

[*] *Project Manager ERC Synergy Project BlackHoleCam*

Overview ETWG

ETWG was convened in the summer of 2013

Objectives:

1. Survey the capabilities at all EHT facilities
2. Establish a set of specifications for future EHT observations
3. Outline a technical developments needed to reach these goals
4. Based on prioritized science objectives, formulate a project roadmap for the EHT that is grounded in technical feasibility with the resources available

Technical Roadmap for EHT









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Tilanus - EHT2014, Perimeter Institute, Waterloo, Canada, Nov 10-14 2014

Survey (future) capabilities

EventHorizonTelescope

	BEAMFORMER	INTERNET	MASER	RX230	RX345	VLBI-BACKEND	VLBI-RECORDER	WVR	REVIEWER
SMTO	n/a	24	y	y	2016?	n	n	n	Shep Doeleman + Dan Marrone
SMA	2014	24	y	y but	y	y	y	n	Jonathan Weintroub
CARMA	2015?	24	y	y	n	y	n	n	Dick Plambeck
JCMT	n/a	24	y	n but	n	n	n	y	Remo Tilanus
APEX	n/a	24	y	2015?	y	y	y	y	Alan Roy
LMT	n/a	24	y	n	n	n	n	n	Shep Doeleman
IRAM-PV	n/a	24	y	y	y	y	y	n	Michael Bremer
SPT	n/a	7-11	2015	2015	2016?	n	n	n	Dan Marrone
ALMA	2015	24	y	y	y	y	y	y	Satoki Matsushita/Shep Doeleman
IRAM-PdB	2017	24	y	y	n	y	y	y	Michael Bremer; Vincent Pietu

RX230

green = compatible with 221.1 LO and IF 5..9 GHZ

Return

		Min IF	Max IF	Sideband	Polarization	Handiness	Circ Waveplate	Remote In/Out	Remote rotation	Comments
		5	10	2sp	dual	linear	y	n	n	
		4	12	dsb	single	linear	y	y	y	Restrictions 5-9; waveplates need installation
		1	9	dsb	dual	circular	n/a	n/a	n/a	
JCMT	y	210	270	4	8	dsb	single	linear	y	n	y	SMA-style mixer is 4-12 GHz (needs installation)
APEX	2015?	214	267	4	12	2sp	dual	linear	y	n	n	New RX being built
LMT	n											RX being planned
IRAM-PV	y	214	267	4	12	2sp	dual	linear	y	n	n	
SPT	2015	221.1	221.1	5	10	2sp	dual	linear	y	n/a	n	Under construction. Single LO freq.
ALMA	y	221	265	5	10	2sp	dual	linear	n/a	n/a	n/a	
IRAM-PdB	y	214	267	4	12	2sp	dual	linear	y	y	n	IF 4-8+8-12

RX345

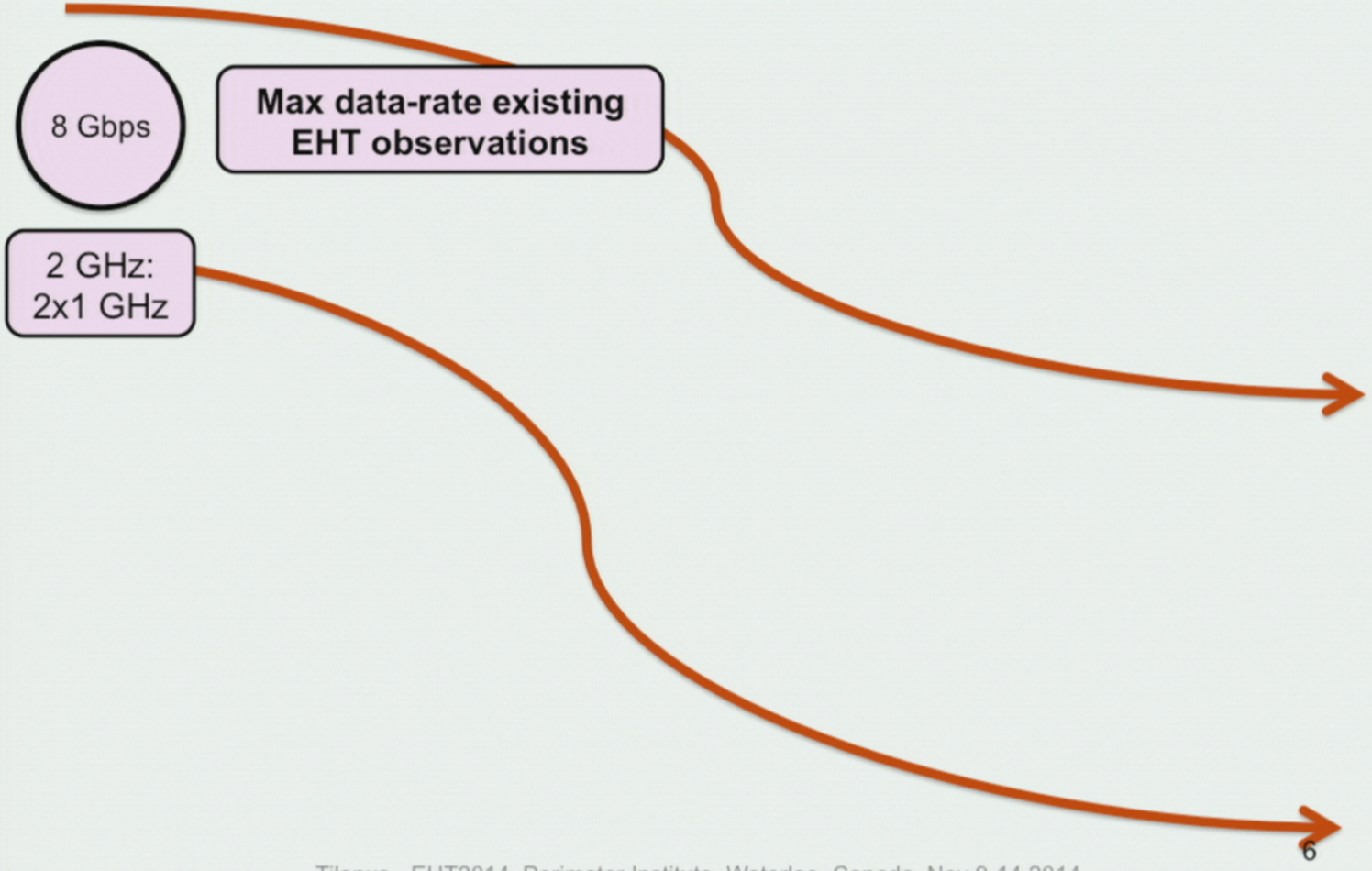
green = compatible with 342.3 LO and I

Return

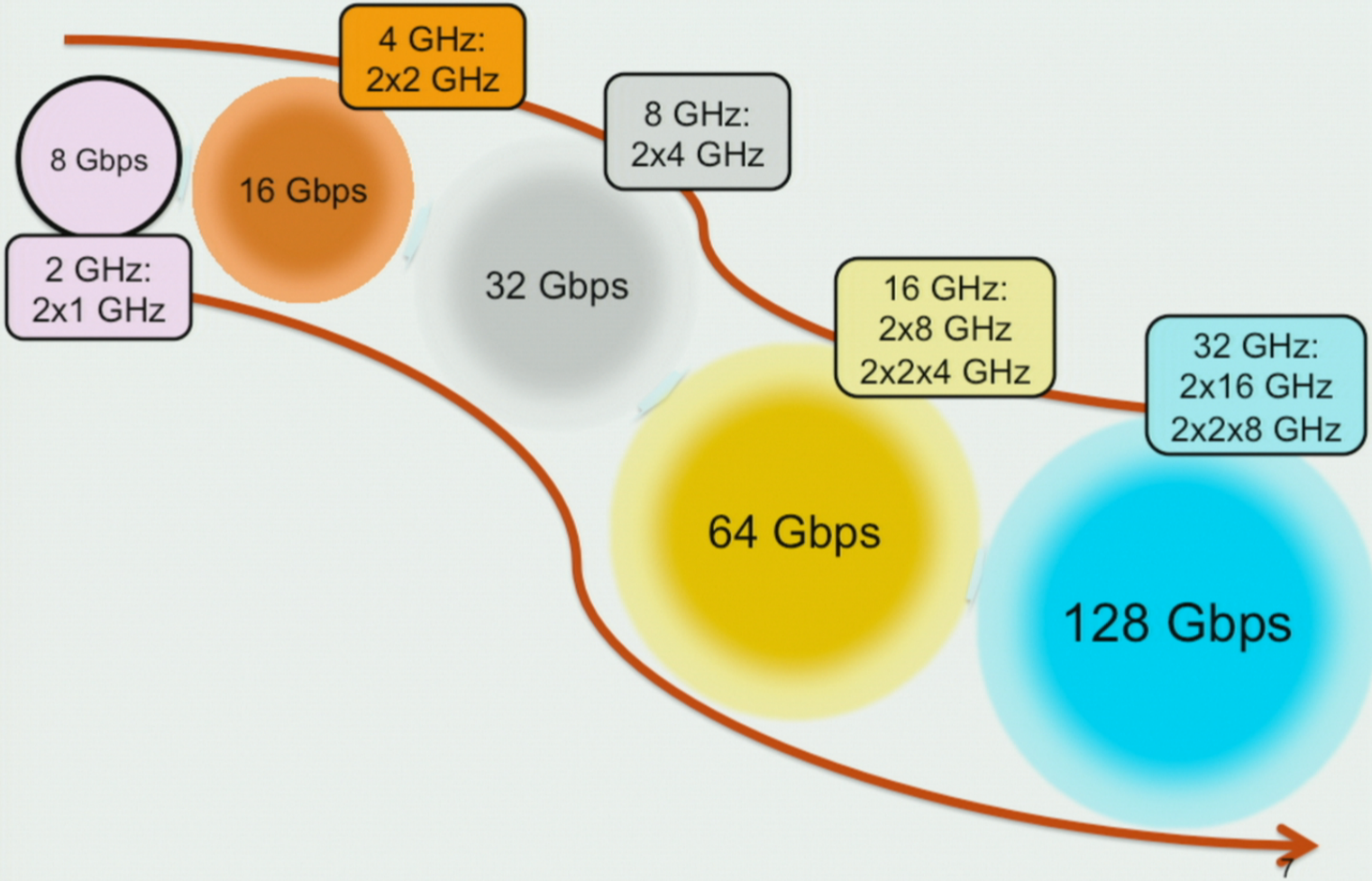
	Available	Min LO	Max LO	Min IF	Max IF	Sideband	Polarization	Handiness				
SMTO	2016?	2837	3657	4	87	2sp	dual	linear	y	n	n	Current mixer high-Tsys.
SMA	y	260	354	4	8	dsb	dual	linear	y	y	y	in dual pol mode LO range is 330 to 345 GHz
CARMA	n											
JCMT	n	325	370	4	6	dsb	dual	linear	y	n	y	Mixers removed!
APEX	y	267	378	4	8	2sp	single	linear	n	n	n	
LMT	n											
IRAM-PV	y	289	3557	4	12	2sp	dual	linear	n	n	n	1/4 plate could be built in-house when frequencies are kn
SPT	2016?	342.3	342.3	4	12	2sp	dual	linear	y	n/a	n	Under construction. Single LO freq.
ALMA	y	283	365	4	8	2sp	dual	linear	n/a	n/a	n/a	
IRAM-PdB	n	289	3557	4	12	2sp	dual	linear	y	y	n	First NOEMA extention does not have 345 GHz

(later today:
Array site reports +
Gopal Narayanan: LMT)

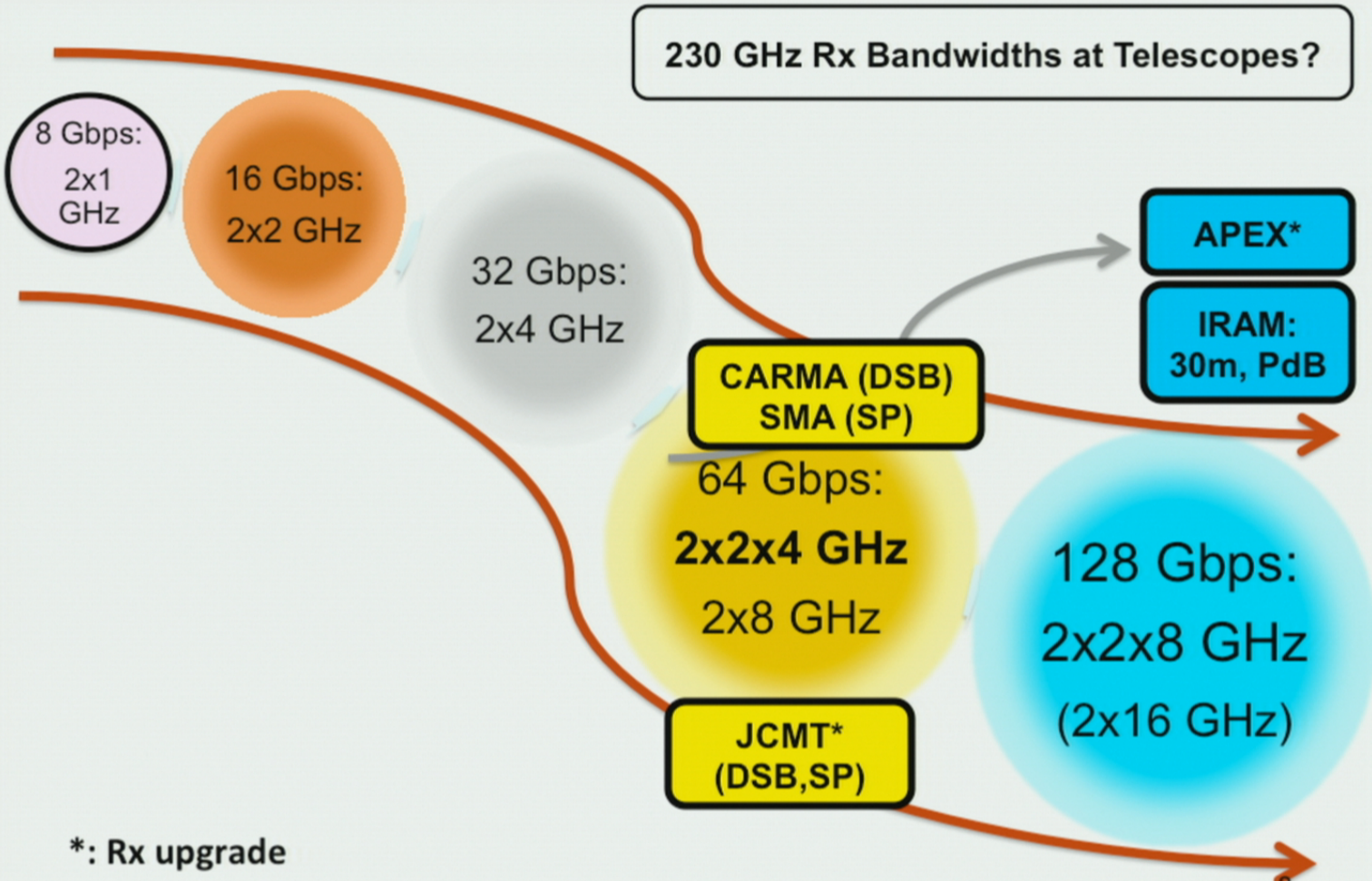
Future mmVLBI bandwidths



Future mmVLBI bandwidths



Future mmVLBI bandwidths: RXs



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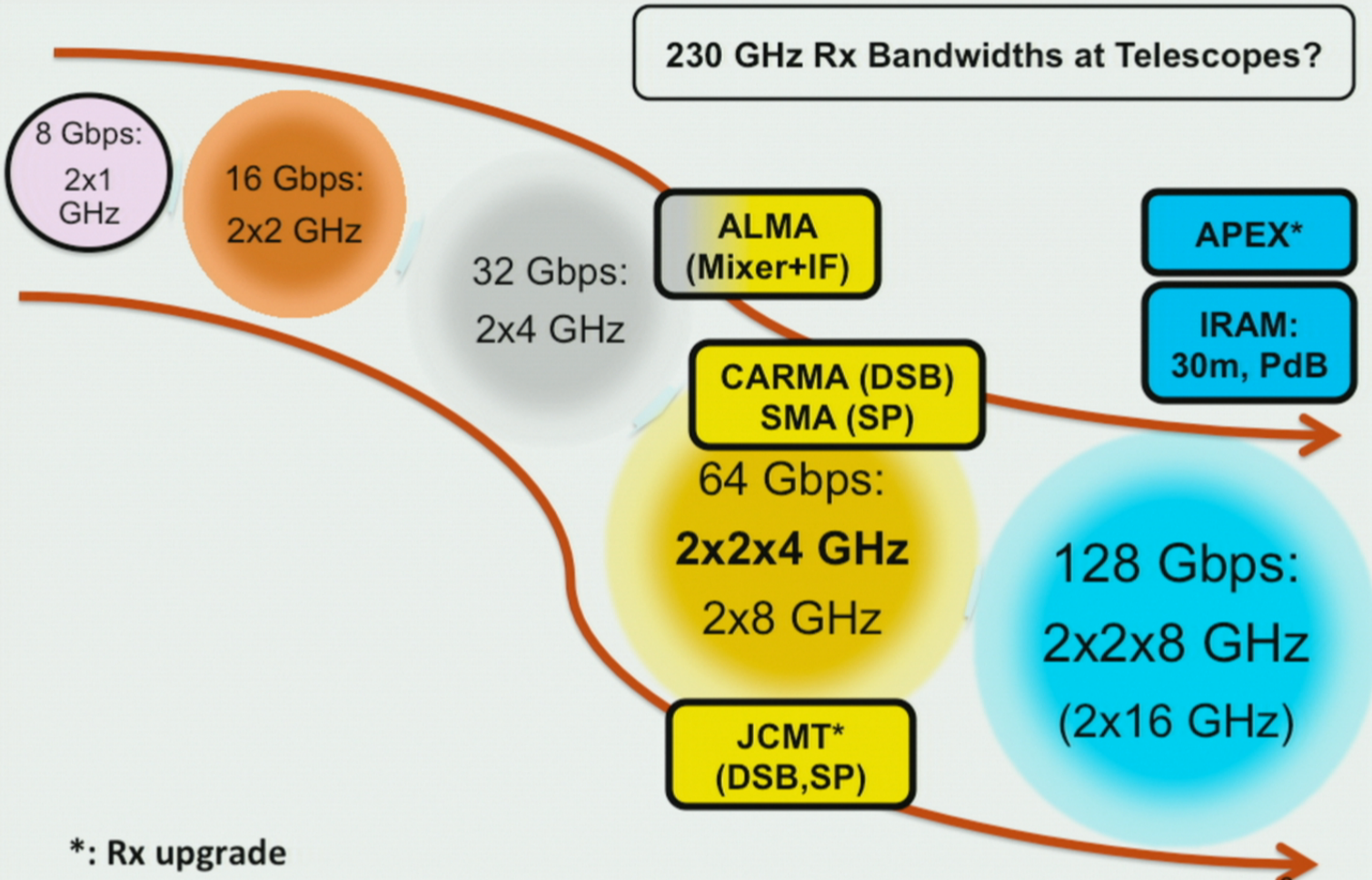
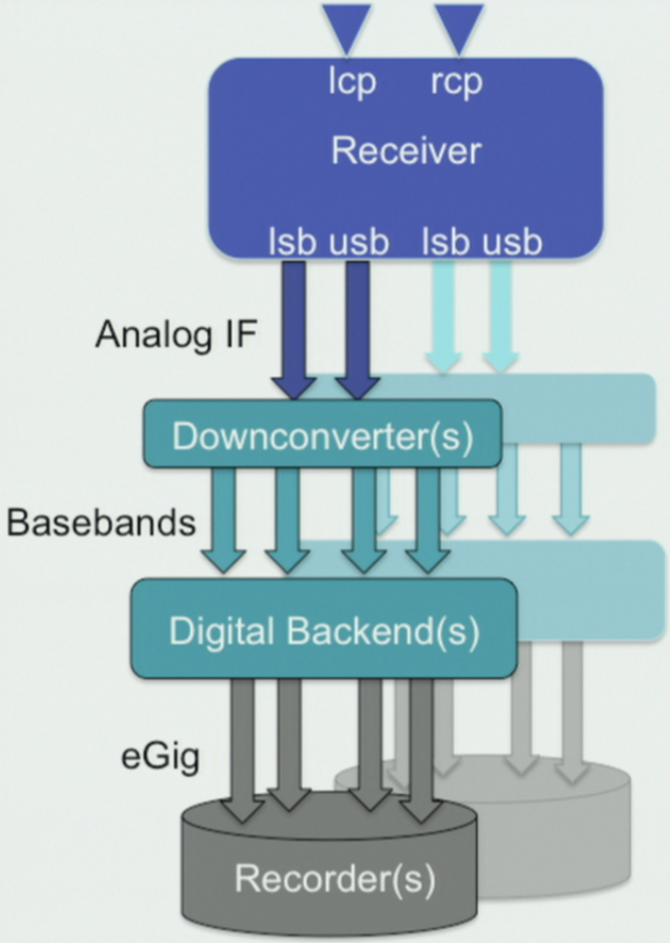


Schematic of VLBI Signal Chain



Single-dish signal chain:

- Downconverter
- Digital backend: 16, 32, or 64 Gbps versions of R2DBE or DBBC3
- Recorder: 16 Gbps Mark 6

(plus lot more secondary equipment and Maser!)

Interferometers:
Beamformer + Recorders
(talk Mike Hecht)

Next-Gen mmVLBI Equipment

R2DBE (SAO)
- 16 Gbps
- 2 x 2 GHz

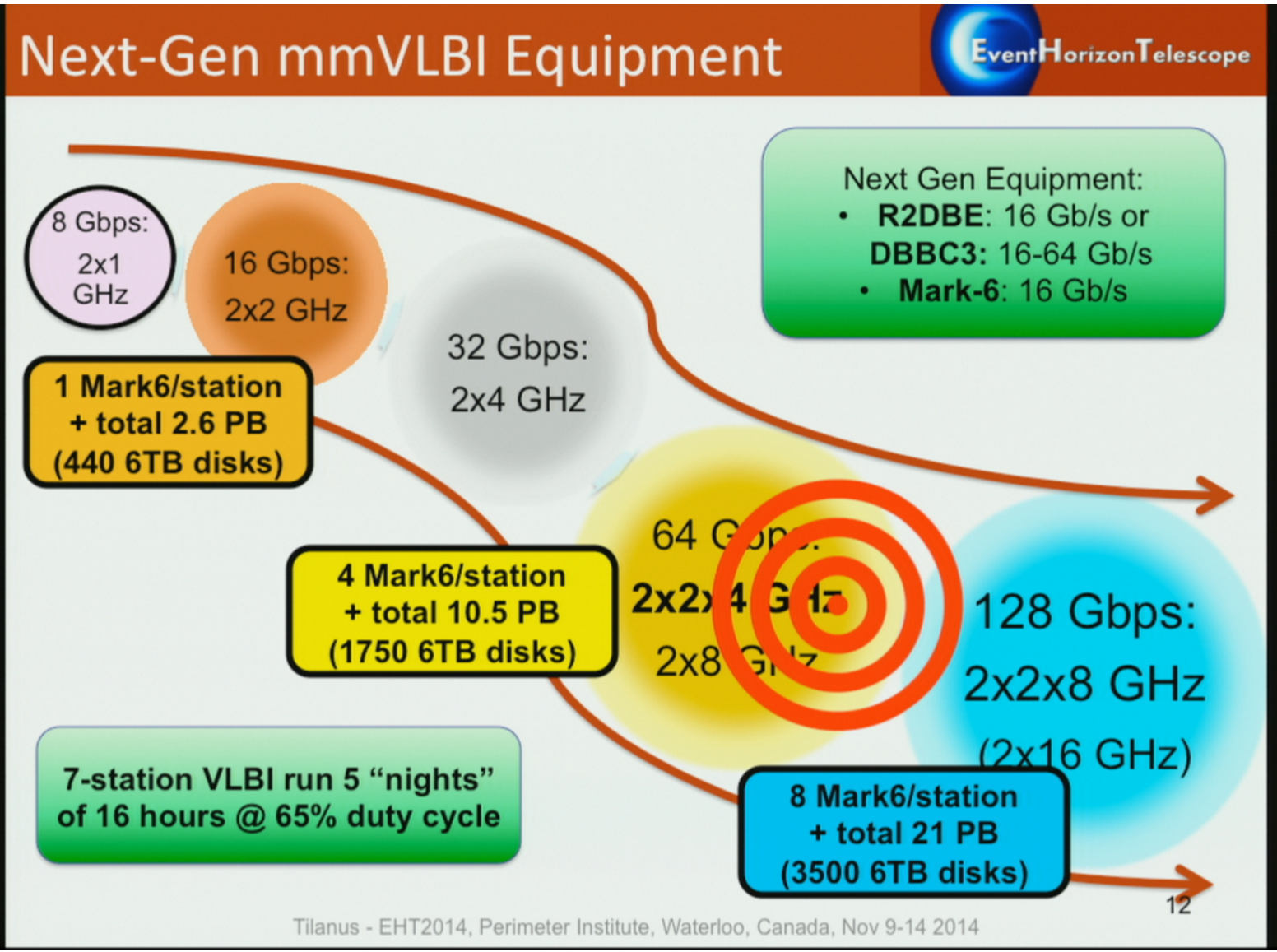
(talk Laura Vertatschitisch)

Mark-6 (Conduant)
- 16 Gbps
- 4 modules
- 32 disks

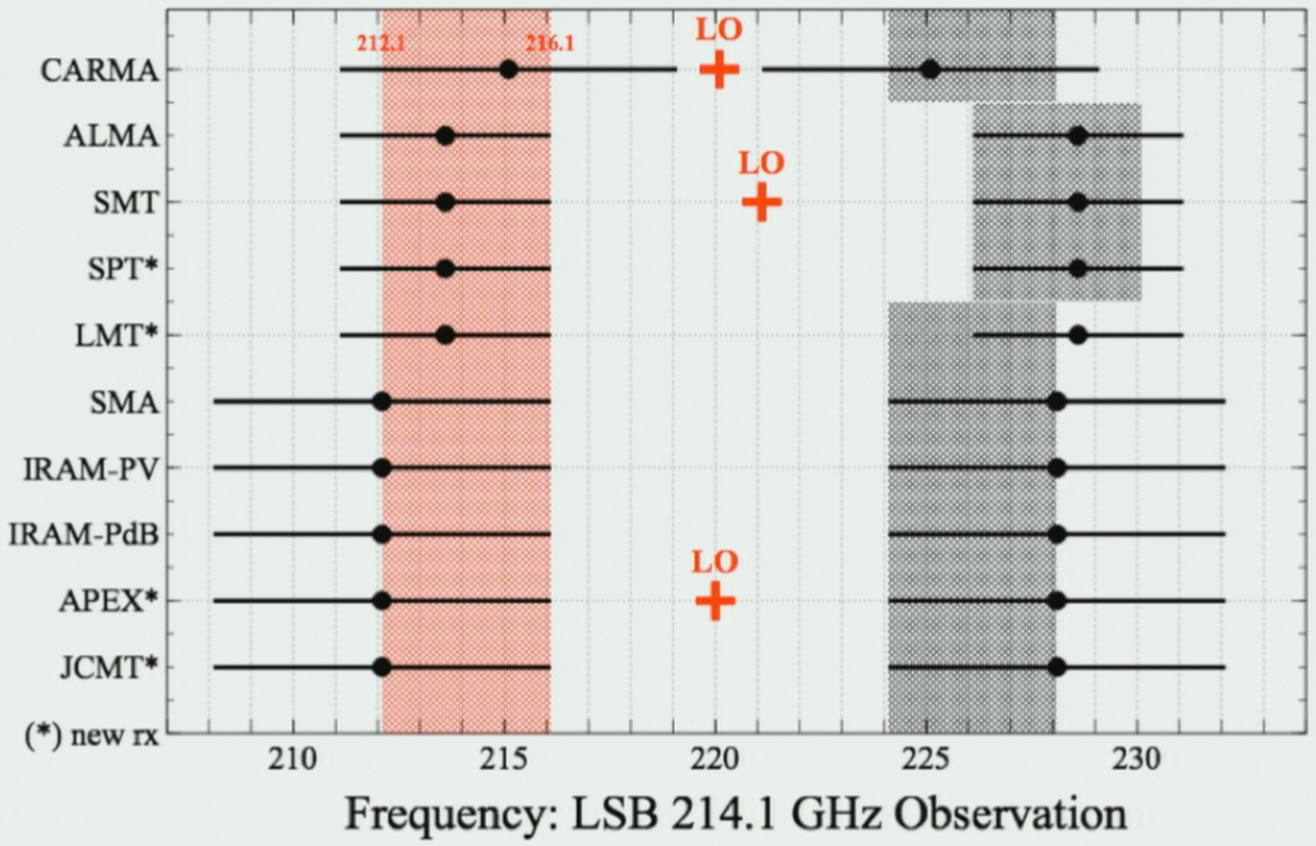
(@6Tb =192 TB)

DBBC3 (INAF/MPIfR/OSO)
- 16 to 64 Gbps
- n x 4 GHz *(Jul 2015)*

Next-Gen mmVLBI Equipment



IF-range 230 GHz (SSB setup)



Next-Gen Downconverter

Haystack
Alan Rogers
Christopher Beaudoin
Mark Derome
Christopher Eckert +
Jonathan Weintroub (SAO)

- For use with the R2DBE: 2x4 GHz to 4x2 GHz in baseband (0-2 GHz)
- DBBC3 will use integrated downconverter

Observing Frequency

Constraints:

- Avoidance of the Galactic CO
  - 230.5379 ± 300 km/s; i.e. v ~ 230.31 – 230.77 GHz
- Avoidance of Galactic 13CO (to a lesser extent)
  - 220.3987, or 220.18-220.62 GHz
- Atmospheric transmission.
- Calibration and e.g. Rx commissioning:
  - Access to e.g. SiO maser line (215.596 GHz)
  - Access to strong spectral lines
- [Performance current wave plates, which are centered on 225 GHz (to a lesser extent)]

(similar for 0.8 mm window)

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LO Freq at 1.3mm: 221.1 GHz

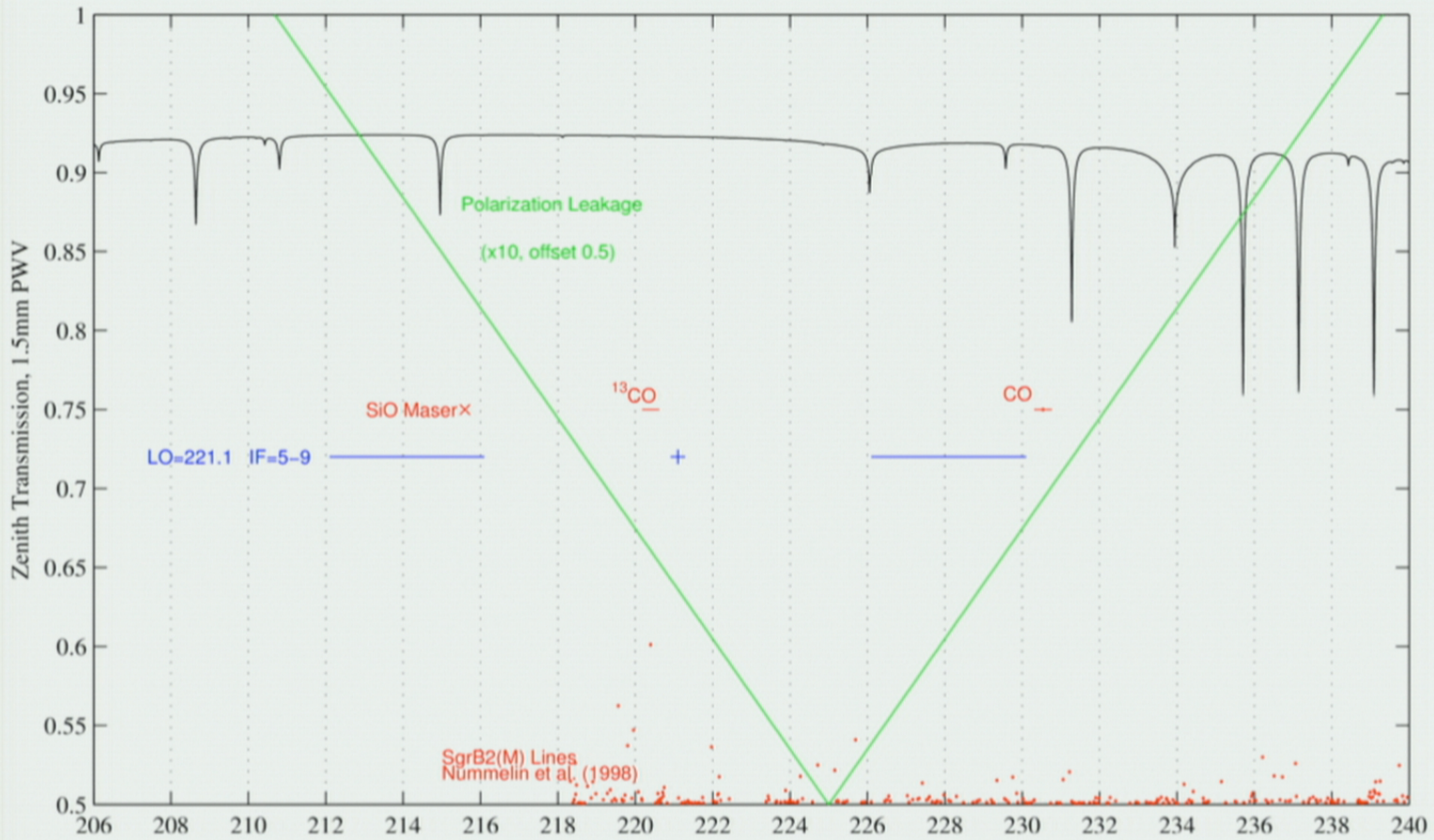


Figure courtesy Dan Marrone

LO Freq at 0.8mm: 342.3 GHz

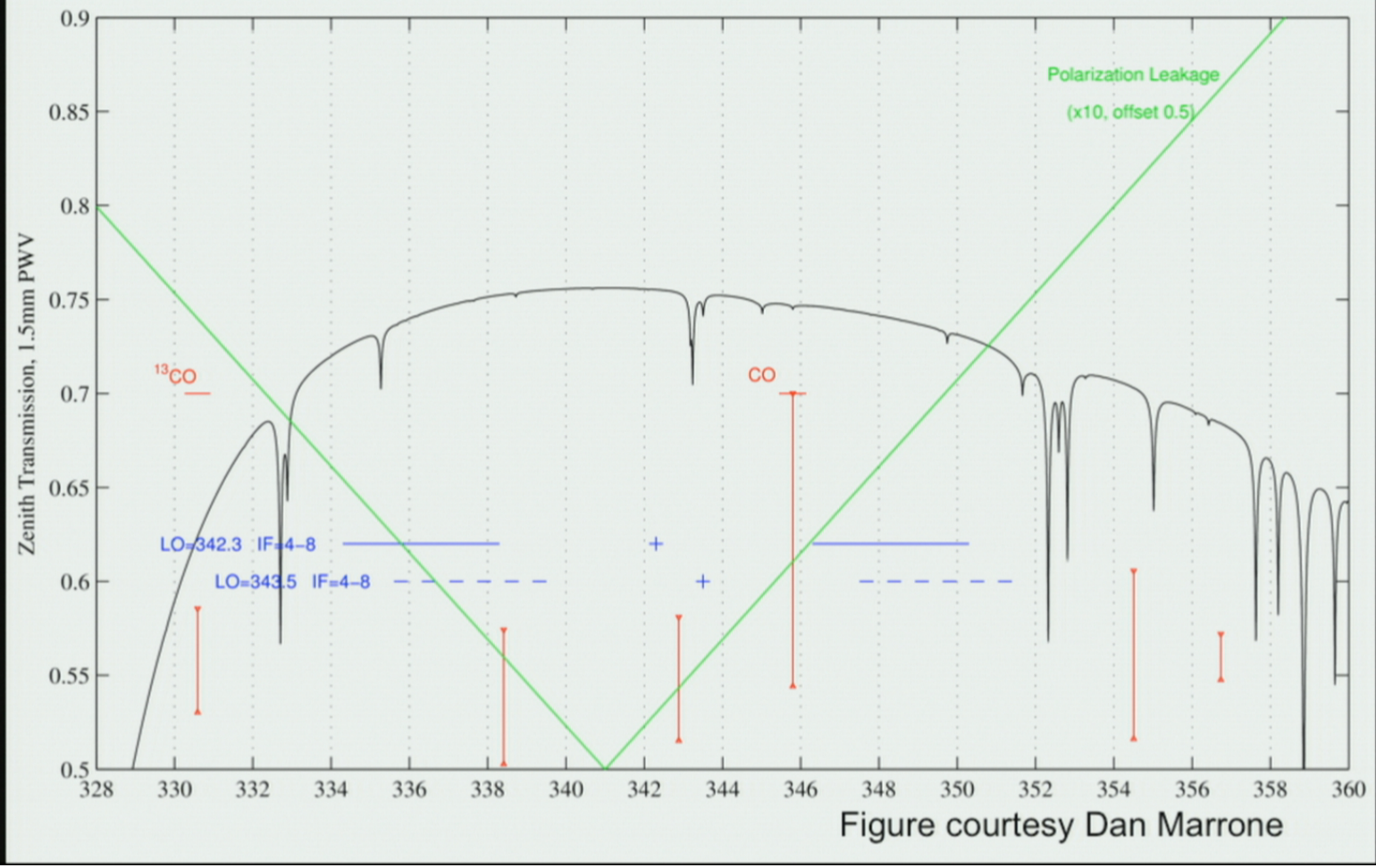


Figure courtesy Dan Marrone

Polarization

In general: Polarizations at different telescopes do not automatically align

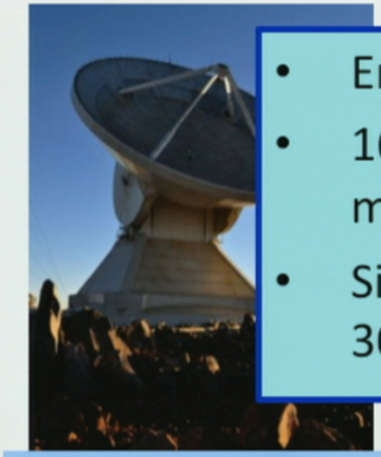
To-date: use polarimeter with 1/4-λ waveplates to convert to circular polarization.

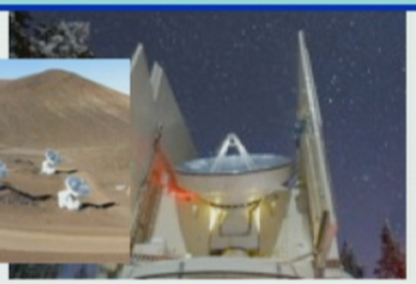
Polarization will be discussed in talks by Dan Marrone and Ivan Marti-Vidal

	Circ Waveplate	Remote In/Out	Remote rotation
SMTO	y	n	n
SMA	y	y	y
CARMA	n/a	n/a	n/a
JCMT	y	n	y
APEX	y	n	n
LMT			
IRAM-PV	y	n	n
SPT	y	n/a	n
ALMA	n/a	n/a	n/a
IRAM-PdB	y	y	n

2015 mmVLBI Campaign

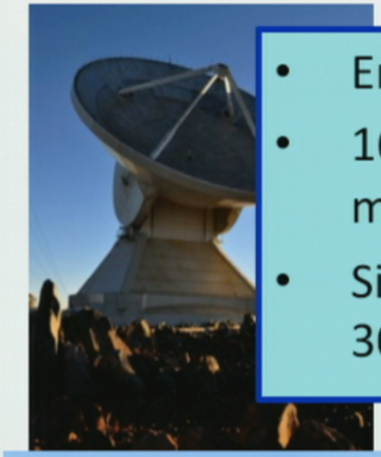
- End of March 2015 up to 5 nights
- 16 Gbps i.e. first use of next-gen mmVLBI signal-chain
- Sites (tentative): APEX, CARMA, IRAM 30M, LMT, SMT, SMA+JCMT, SMT, SPT

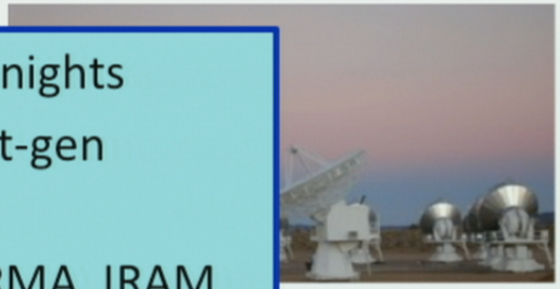




2015 mmVLBI Campaign





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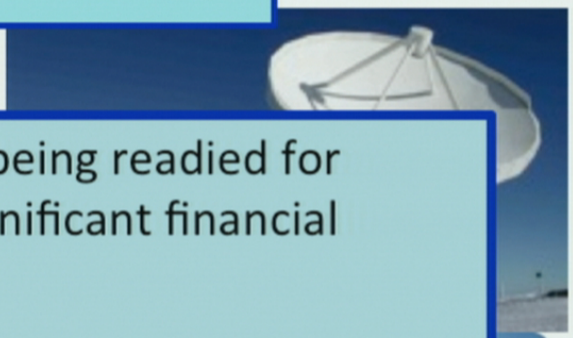
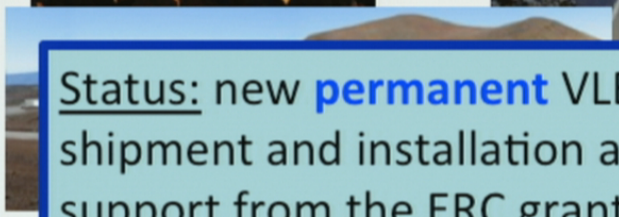
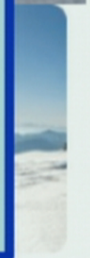




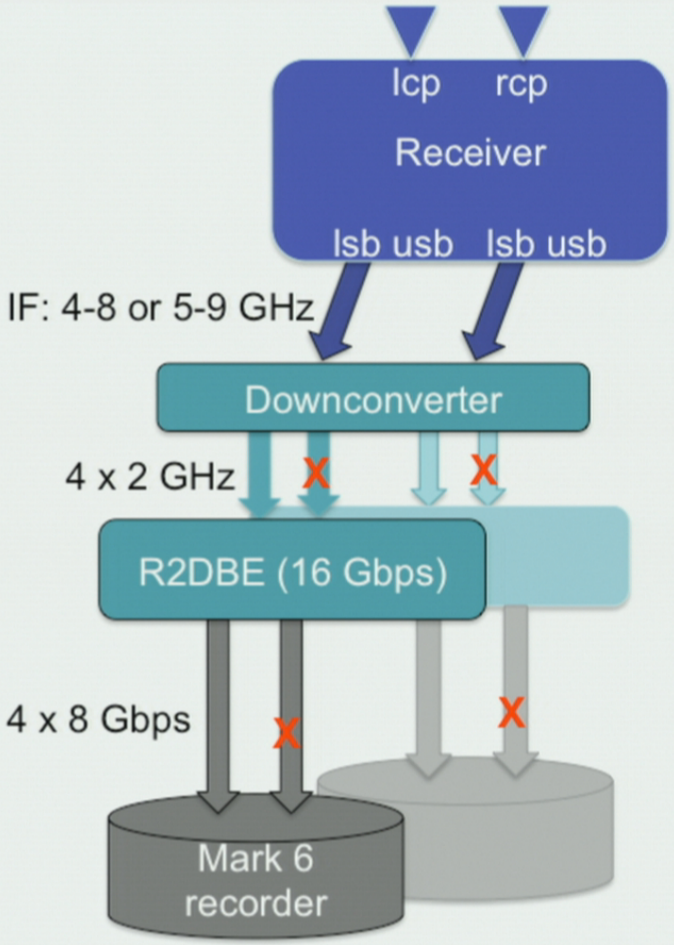


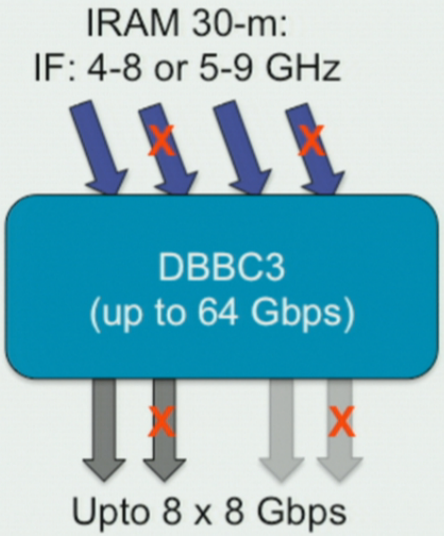
Status: new **permanent** VLBI equipment being readied for shipment and installation at sites with significant financial support from the ERC grant.

e.g.

- BDCs and R2DBEs ordered and being assembled
- Mark-6 recorders received, modules on order
- 6Tb disks being tested in (new) hypobaric chamber at Haystack in anticipation of mass-order

EHT – 32 Gbps (2 x 4 GHz 1SB/DSB)





X: *spring 2015 will use two channels for 16 Gbps*

Roadmap beyond 2015

Roadmap to full system will be presented in next talk by Dan Marrone

- Correlation *(talk Geoff Crew)*
- Semi turn-key
- Quality assurance

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